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21OCT03 E846144-1 002651
P01/7700 0.00-0324519.8

1/77

Request for grant of a patent

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1.	Your reference	607GB
2.	Patent application number *(The Patent Office will fill in this part)*	0324519.8 21 OCT 2003
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	Renishaw plc New Mills Wotton-under-Edge Gloucestershire, GL12 8JR
	Patents ADP number *(if you know it)*	2691002
	If the applicant is a corporate body, give the country/state of its incorporation	United Kingdom
4.	Title of the invention	Metrology Instruments
5.	Name of your agent *(if you have one)*	M J Fowler et al
	"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	Renishaw plc, Patent Department New Mills Wotton-under-Edge Gloucestershire GL12 8JR
	Patents ADP number *(if you know it)*	2691003

		Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*
6.	If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number	–	–	–

		Number of earlier application	Date of filing *(day / month / year)*
7.	If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application	–	–

8.	Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:* *a) any applicant named in part 3 is not an inventor, or* *b) there is an inventor who is not named as an applicant, or* *c) any named applicant is a corporate body.* *See note (d))*	Yes

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form	0
Description	11
Claim(s)	0
Abstract	0
Drawing(s)	5 +5

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Priority documents	0
Translations of priority documents	0
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	0
Request for preliminary examination and search *(Patents Form 9/77)*	0
Request for substantive examination *(Patents Form 10/77)*	0
Any other documents *(please specify)*	0

11. I/We request the grant of a patent on the basis of this application.

Signature Date 16.10.03

AGENT FOR THE APPLICANT

12. Name and daytime telephone number of person to contact in the United Kingdom A Iles 01453 524524

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METROLOGY INSTRUMENTS

This invention relates to metrology instruments and in particular lightweight and thermally stable metrology instruments.

The term metrology instrument includes probe heads, probes, styli and non-Cartesian metrology frames.

It is known to provide probing apparatus for the surface scanning of articles to enable reproduction of an article or to ensure that manufacture of an article is accurate. It is desirable to increase the speed at which articles are scanned in order to reduce the time taken by this process. However, in order to maintain accuracy and keep within tolerance range when working at higher speeds, the effect of acceleration forces that the probing apparatus undergoes during a measurement process must be minimised. This requires a light and stiff stylus and probe structure to reduce bending during movement. Additionally, in order that resolution is maintained at higher speeds, so any fine detail of a surface profile is not lost, the metrology instrument must have a high frequency response.

Another issue is the reproducibility of the measurements. One parameter that affects this is ambient temperature. All materials change dimensions as the temperature changes however, each material is affected differently. Along with the rate of dimensional change, the time it takes for a material to equilibrate is also important. Any expansion/ contraction of a probe structure introduces errors in

the measurement process. Thus, the thermal stability of the whole probe structure is also important.

The present invention provides a metrology instrument comprising at least one sheet of material which, in use, is folded to form a three dimensional structure.

The use of such a three dimensional folded structure means that a metrology instrument of the required stiffness can be made from thinner sheets of material resulting in a lower weight thus lower inertia article.

Preferably, the at least one folded sheet is joined. The joining method may include one or more of the following techniques: 'tabs and slots'; folded tabs and slots; gluing; welding; attaching to another framework. This further increases the rigidity of the structure formed from the at least one sheet of material.

In a preferred embodiment, the at least one sheet is made from a thermally stable material. A thermally stable material is one that has a coefficient of thermal expansion of ≤ 6ppm/°C. Preferably, the thermal expansion of the material is ≤ 2ppm/°C.

According to a second aspect of the present invention there is provided a method of manufacture of a metrology instrument comprising:

providing at least one template of the metrology instrument from a sheet of material;

folding the at least one template to produce the metrology instrument.

Preferably, the sheet of material is made from a

thermally stable metallic material. In this embodiment, the at least one template is preferably manufactured by removing surplus material from the sheets of material. The surplus material may be removed by laser machining, stamping, photo chemical machining (for example photo-etching and chemical machining) or any other suitable technique. The technique used will depend on the material properties of the sheets.

Preferably the forming comprises folding the at least one template into a three dimensional structure which, for added stiffness, may include walled cavities within the structure and optionally welding overlapping portions of the at least one folded template.

The invention will now be described by example and with reference to the accompanying drawings, of which:

Figs 1a and 1b show a template and equivalent folded structure;

Fig 2 shows an isometric view of a folded structure according to the invention;

Fig 3 shows a probe according to the invention;

Fig 4 shows a metrology instrument according to the invention;

Fig 5a shows a side view through the folded structure of Fig 2;

Fig 5b is a cross-section A-A through the side view of Fig 5a; and

Figs 6a and 6b shows a stylus arm according to the invention.

Fig 1a shows a template 10 which comprises four rectangular sections 12 and two square sections 14.

The square sections 14 each have a central cut-out circular region 16. Each section is joined to at least one other section by a seam 18.

The configuration of the different sections of the template is determined by the final shape of the structure that is to be created. In this case, the final structure is a box 11 (Fig 1b) having closed side walls 12 and a circular opening 16 at each end defining an open tube which passes through the box 11. The template 10 is converted into the final structure by folding the template at each seam 18.

The template is formed from a metal sheet which has been cut to shape by any one of a number of standard techniques (for example laser machining, stamping, photo chemical machining).

The locations of folds can be accurately determined by suitable jigging or, either full or partial thickness chemical or laser machining. If full thickness machining is used, a series of perforations are machined along the fold line forming a weakness which is easier to bend. The perforations may comprise a series of slots. If a partial thickness machining process is preferred, the material at the point where a fold needs to be made is partially machined defining a seam which again weakens the material. Partial machining is a well known method achieved by carefully timing of the process so that portions of sheet which are exposed on two faces to the machining chemical or laser are fully machined during the process thus, portions of a sheet with only one face exposed are only partially machined. Defining the fold-lines is

advantageous for three reasons firstly, this makes the material easier to bend into shape secondly, reproducibility of parts is increased and thirdly, the need for associated jigging can be obviated.

Once the sheet has been folded it can be secured in place by any of a number of known techniques. Fig 2 shows two folded structures 20, 22 which have been secured using slots 24 and corresponding tabs 26. The tabs 26 are inserted through slots 24 and then are bent through substantially 90° (not shown). The tabs and slots are accurately produced preferably during the same process as that when the template is produced and enable manufacture of the structure without the use of jigging. If the joints are welded to prevent removal of the tabs from the slots, the structure can be welded as is, without the requirement for a welding jig.

The folding and securing of the template results in a three dimensional structure having, where appropriate, walled cavities 28 within the overall structure to provide a stiff structure that does not bend appreciably either under the weight of the whole structure or during use. By having walled cavities, the sheet thickness used may be reduced resulting in reduced weight of the structure without a corresponding reduction in rigidity or stiffness.

The template may include a series of partial through thickness machined cut-outs which selectively reduce the thickness of the template by around a half resulting in further weight savings (see Fig 6b).

Referring now to Figs 5a and 5b which show a side view

of the folded structure of Fig 2 and cross-section A-A through the side view respectively, when a walled cavity has been used, the inner cavity formed 128 can be filled with a foam to stiffen the structure and provide extra protection against buckling. Alternatively, foam blocks are used which are bonded to the folded structure. The inclusion of foam allows thinner sheets, or even partial through thickness sheets to be used without a reduction in desirable mechanical properties. A foam filling advantageously also damps the structure reducing the occurrence of back-to-earth vibrations from the movements of the structure.

In this example, the three-dimensional structures are additionally spot welded (laser, resistance, E-beam or ultrasonic for example) in order to ensure that the tabs do not move within the slots over time (which movement could affect any measurements made by a probe structure). The spot welding is conveniently carried out where two walls of the structure abut or overlap.

Figure 3 shows a probe structure 30. The probe structure 30 is releasably connected to a quill or spindle 32 of, for example, a machine tool, CMM or other measuring machine. The probe structure 30 includes a probe 34 which is mounted at one end to the quill 32. At the distal end of the quill, a stylus 38 is releasably connected to the probe 34, optionally via a stylus arm 36.

In the simplest embodiment of the invention, the probe 34 is mounted in a fixed relationship to the quill 32. In this situation, the movements of the stylus tip 40

are controlled by the movements of quill 32 with respect to a gantry (not shown) usually in x, y and z directions. When the quill 32 moves, there is a chance that the probe 34 and in particular any stylus arm 36 may bend due to inertial forces and/or acceleration forces. Any such bending will result in an inaccuracy in a measurement as the stylus tip will have bent away from its nominal position. In order to minimise any such bending, one or both of the probe 34 and stylus arm 36 are manufactured as a folded three dimensional structure.

The probe can be contact or non-contact. Contact probes include touch trigger i.e. on/off, for example electrical and strain gauge; and scanning probes where the amount of deflection is measured for example, optical systems. Non-contact probes, where the surface of the workpiece is not touched include optical, inductance and capacitance systems.

The example in Fig. 3 uses a contact probe having an optical system in order to achieve a lightweight probe structure. Information from the stylus tip 40 is transmitted through a hollow folded stylus arm 36 and the probe structure optically, preferably by a laser system. One such system is described in WO 00/60310 which is herein incorporated by reference. The system briefly comprises shining a laser internally along the probe structure from a point distal the stylus tip to the stylus tip 40 and reflecting the light back to a receiver housed adjacent the incident beam. When the stylus tip is deflected, the lateral displacement of the reflected beam is detected indicating that the stylus tip 40 has contacted a surface.

Referring now to Figs 6a and 6b, the stylus arm 36 is cone shaped and manufactured from a sheet 60 of thermally stable material which is laser spot welded along a seam 62 which in this case lies longitudinally along the length of the stylus arm. The stylus arm 36 is not limited to being cone shaped, any structure which is stiff enough not to bend during movement of the probe and that has a central hollow to enable the passage of light through the stylus arm 26 to the stylus may be used. An alternative shape is triangular.

Examples of thermally stable metallic materials are Invar, Kovar, Inconel, Monel, Nichrome, although other suitable alloys will be apparent to the skilled person. The sheets are ≤ 1.5mm thick. Preferably, the sheets are 0.05-0.9mm thick. More preferably, the sheets are 0.1-0.5mm thick.

Figure 4 shows a probe structure 42. In this example the probe is motorised i.e. the probe head 46 is movable independently of any quill 44 movements. The probe head 46 is mounted to the quill 44 at one end via a motor 52, bearing and encoder (not shown). The other end of the probe head 46 is connected to an optional stylus arm 36 and a stylus 38.

The use of a motorised probe head is advantageous particularly when scanning an article as it enables the stylus tip 40 to be moved faster than when quill movements solely control the movement of the stylus tip. Such a motorised probe head is described in EP402440. However, a side effect of having a motorised

probe head is that is that on top of any external thermal fluctuations which will cause dimensional change in the probe structure, the motors produce heat when in use.

In order to mitigate this internal thermal effect, the motor 52 is mechanically isolated from the probe structure. This is achieved by connecting a thermally stable structure 54 between the quill 44 and the probe head 46 thus stabilising the distance. The motor 52 will expand due to both internal and external influences, and in order to accommodate this thermal expansion, the quill 44 has a hollow 56 of dimensions capable of housing the motor. This therefore provides a low expansion mount for a probe head. The provision of a lighter structure also mitigates the thermal effects of having a motorised probe.

The thermally stable structure 54 can be a single folded and joined sheet of a thermally stable material (for example as shown in Fig 1). Additionally it may, comprise four rods of thermally stable material forming four corners of the structure (which can be located accurately using machined locating holes 15, Fig 1), with optional cross members linking adjacent rods. The use of such rods enables thinner sheets of material to be used in the structure without a reduction in stiffness.

The probe structure may be attached to a quill or spindle which is moved manually or automatically. For both situations, the manner and method of moving the probe structure in each dimension will be apparent to those skilled in the art. An example of a manually

moved structure is described in EP392699. An example of an automated structure is described in US6047612.

In both circumstances, having a thermally stable probe structure is important. For manually moved probe structures, reduced weight is advantageous as it means that the structure requires less counterbalancing to enable comfortable manual movement. It also reduces the inertia of the structure so control of any movement is increased.

For automatic movement, reduced weight is also advantageous. It means the speed of scanning can be increased as the inertia of the structure is proportional to its mass. Current systems generally operate at 5mm/s although speeds of 50mm/s are possible. The reason that the slower speed is used is partially due to the risk of loss of probe contact with an article being scanned, partially to reduce the chance of breakage of the probe structure when initially contacting a surface, and partially due to the frequency response of traditional structures results in a loss of high frequency data. The probe structure described herein is capable of higher speeds, up to around 500mm/s, regardless of orientation and providing the same metrology performance as at lower speeds of movement.

Figs 6a and 6b show a template 60 for a stylus arm 36. The template 60 has been partially etched 64 to reduce the weight of the stylus arm 36. In this example, due to the pattern of chemical or laser machining used, this results in the unmachined parts becoming reinforcing ribs 66 which stiffen the structure.

In some circumstances, full machining of holes, similar to the perforations used to form a fold line, may be preferred to partial machining as it provides increased reduction in weight of the object in question however, to prevent ingress of dirt or other matter which may affect the functioning of the working parts of the metrology instrument, full machining should only be used where appropriate. If the foam filled embodiment is utilised, this will help prevent any such ingress when full machining is used.

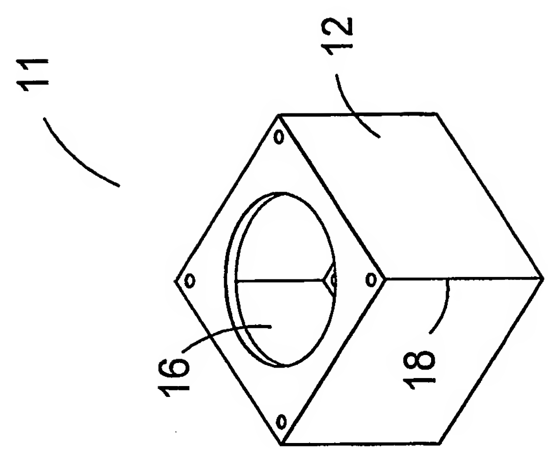


Fig 1b

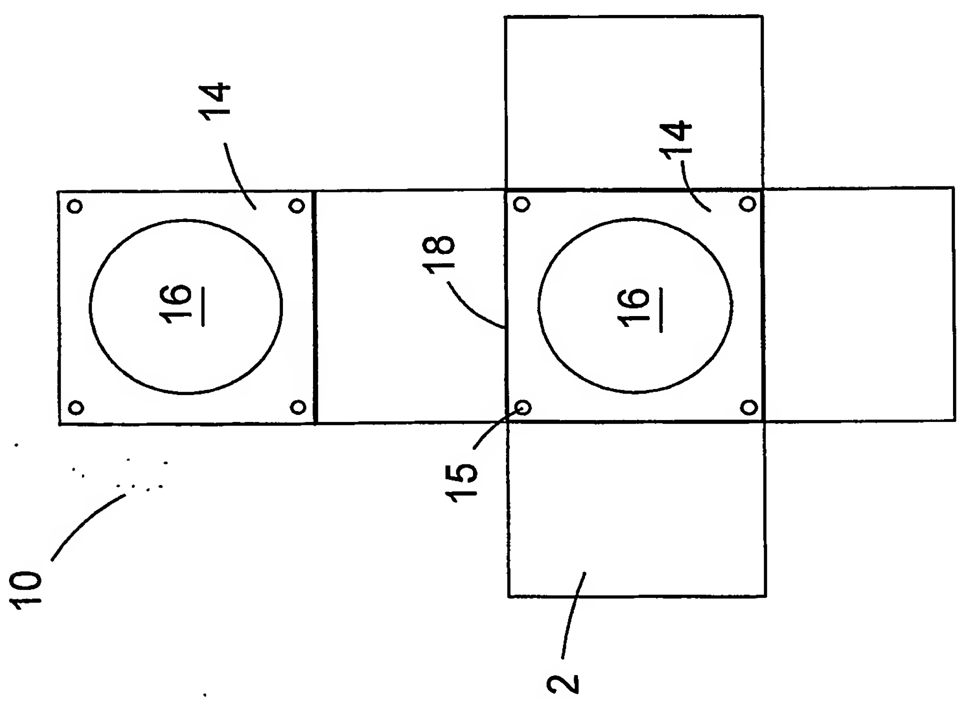


Fig 1a

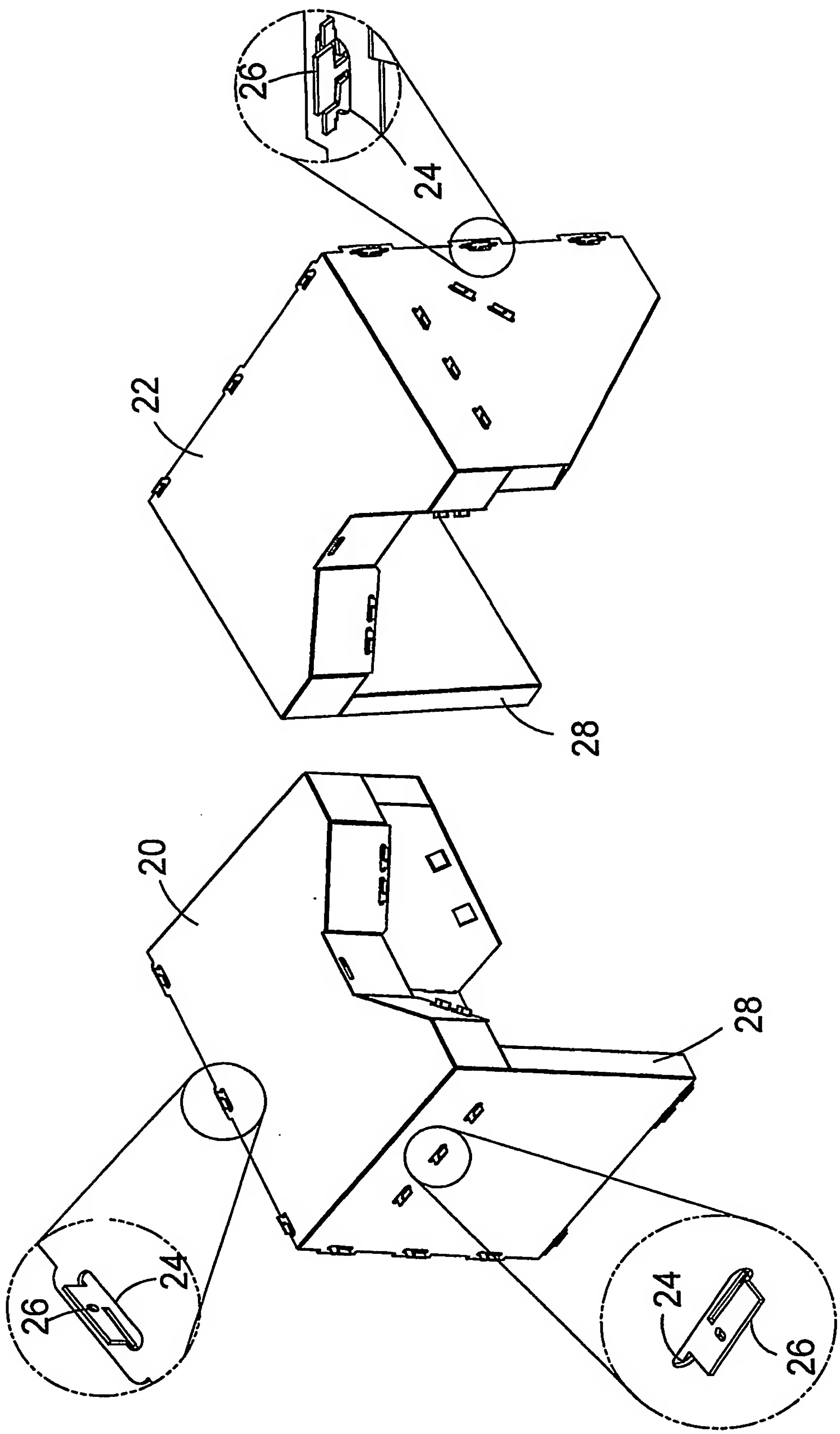


Fig. 2

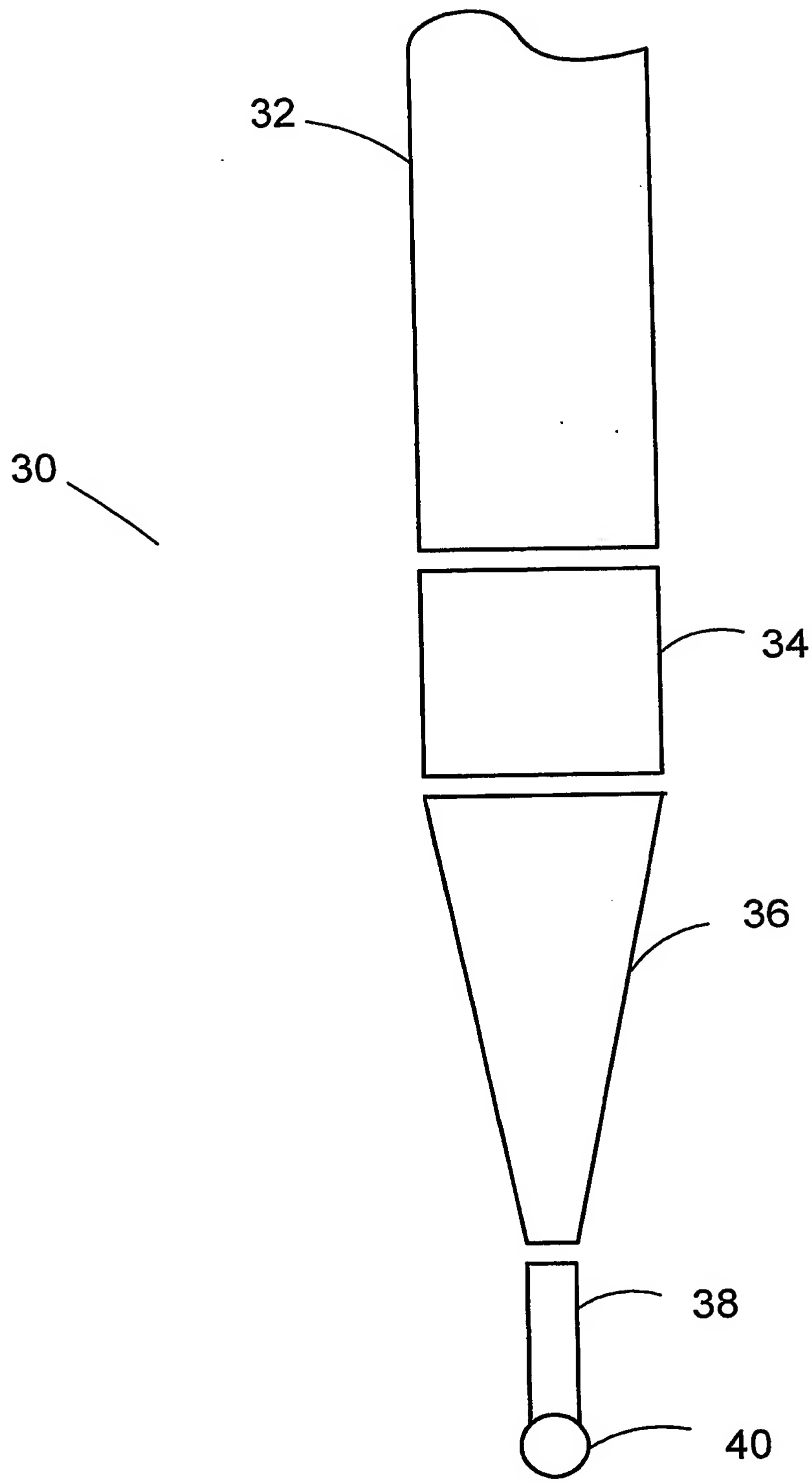
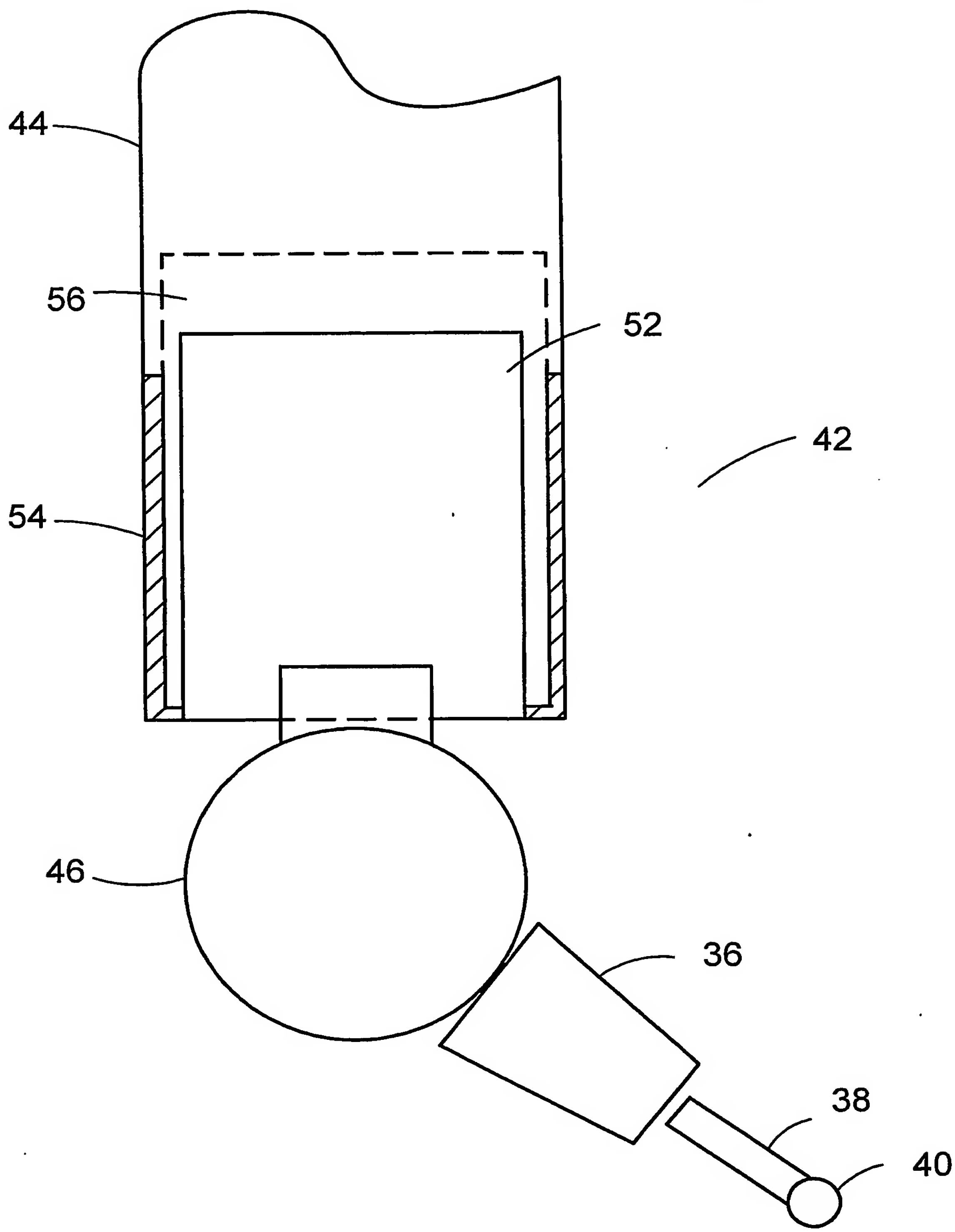


Fig. 3

Fig. 4



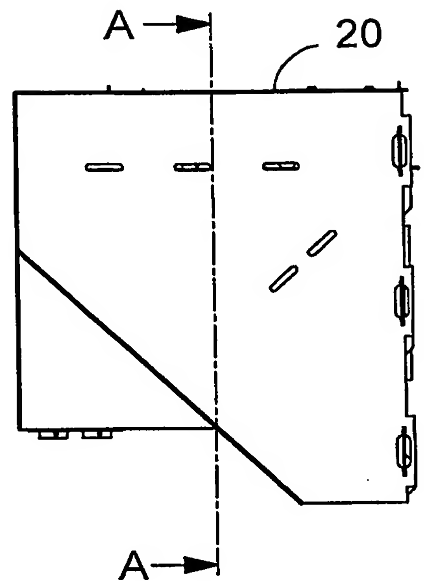


Fig 5a

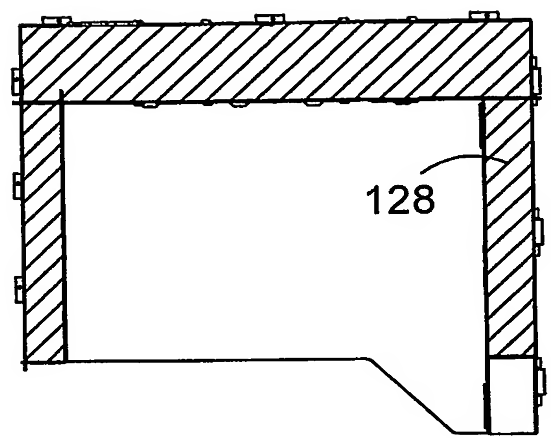


Fig 5b

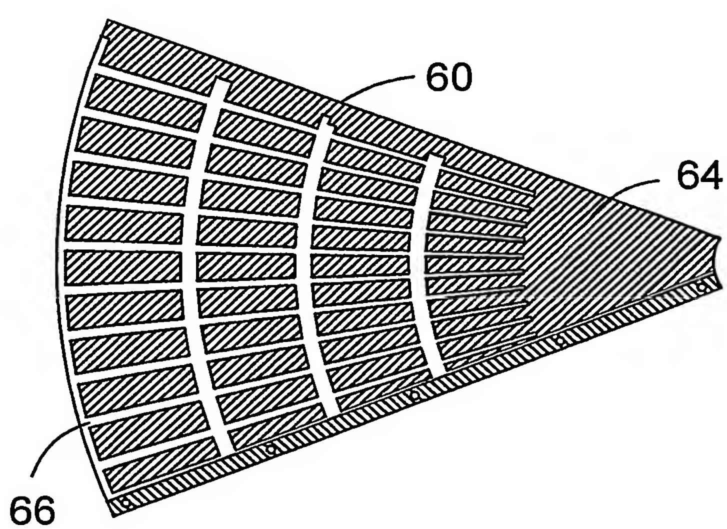


Fig 6a

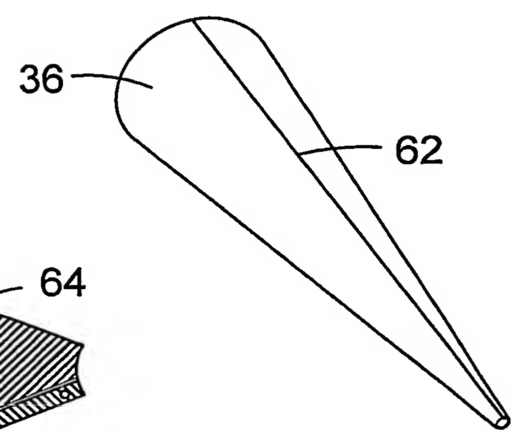


Fig 6b

Document made available under the Patent Cooperation Treaty (PCT)

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